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Born to adapt, but not in your dreams

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Abstract

The brain adapts to changes that take place in the body. Deprivation of input results in size reduction of cortical representations, whereas an increase in input results in an increase of representational space. Amputation forms one of the most dramatic disturbances of the integrity of the body. The brain adapts in many ways to this breakdown of the afferent–efferent equilibrium. However, almost all studies focus on the sensorimotor consequences. It is not known whether adaptation takes place also at other "levels" in the system. The present study addresses the question whether amputees dream about their intact body, as before the amputation, or about the body after the amputation and whether the dream content was a function of time since the amputation and type of amputation. The results show that the majority of the dreamers reported dreams about their intact body although the mean time that elapsed since the amputation was twelve years. There is no clear relation with the type of amputation. The results give modest evidence for the existence of a basic neural representation of the body that is, at least, partly genetically determined and by this relatively insensitive for changes in the sensory input.

Keywords: Body image; Body schema; Dreams; Amputation

1. Introduction

Neural representations of the limbs are continuously updated by our movements. Repetition of movement leads to the strengthening of these representations, whereas inactivity or non-use results in the shrinkage of these representations. In a landmark experiment Merzenich et al. (1983) showed that if a body part becomes less active, such as after deafferentation, its topographical representation in the somatosensory cortex shrinks. Dramatic changes in the cortical topographical organization occur after amputation. More than two decades

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ago Merzenich et al. (1984) showed that digit amputation in a monkey resulted in an increased cortical representation of the adjacent digits. Amputations in humans produce similar effects (Knecht et al., 1996, 1998).

Neural adaptations take place not only as a result of the deprivation of input, but also as a result of an increase of input. Gaser and Schlaug (2003) showed that extensive musical training resulted in multi-regional changes in the brain (gray matter volume). Even simple movements, repeated over a short period of time, are effective in inducing cortical representational changes (Classen, Liepert, Wise, Hallett, & Cohen, 1998; Van Mier, Tempel, Perlmutter, Raichle, & Petersen, 1998).

Hence, the adult human brain is not a rigid system but a system that continuously undergoes plastic changes after alterations in the sensory flow from peripheral receptors and nerve fibers. This flow of multiple sensory stimuli as a result of action (and perception) is for a large part responsible for the (conscious) awareness of the body, which is termed the body scheme or body image.

Against this background, it can be asked whether less voluntary and less conscious processes adapt as rapidly and easily as the sensorimotor system. For example, does the content of dreams change as a result of changes that take place in the body?

Although no consensus exists as how to define dreaming, one could argue that dreams are the result of the subconscious brain processing our waking reality. A more formal definition is a non-conscious electrophysiological state while the body is alive (Pagel et al., 2001). According to Ramachandran and Rogers-Ramachandran (1996) a dream can be conceived of as a series of images, ideas, emotions, and sensations occurring involuntarily in the mind during certain stages of sleep. Furthermore, they argue that in dream-states the brain tries to interpret random impulses from the pons as sensory input, producing the vivid hallucinations we know as dreams, whereby the interpretation of the sensory input is often based on past experience (Ramachandran & Rogers-Ramachandran, 1996). Dreams may have an emotional or cognitive function in that they create a "virtual reality" constructed of internally generated images that, indeed, may represent memories, fears or whishes (Ramachandran & Blakeslee, 1998). Recent neuro-scientific evidence indicated that sleeping and dreaming, play a role in off-line memory reprocessing (Stickgold, Hobson, Fosse, & Fosse, 2001). Also Revonsuo (2000) argued that the content of dreams is not random, but organized and selective. He indicated that dream content is consistently and powerfully modulated by certain types of waking experiences.

The latter arguments form the starting point for the present study. When past and actual experiences play a role in the content of dreams, it becomes an intriguing question whether changes in the conscious awareness of the body in amputees will lead to changes in the contents of their dreams.

We asked whether subjects, who underwent a lower and/or upper limb amputation, dream about themselves as *prior to the amputation* (moving with intact limbs) or as *after the amputation* (moving with a prosthesis).

As far as we know, this is the first study ever that attempts to answer this question, maybe with the exception of an older phenomenological study that addressed, influenced by a psychoanalytic framework, the wish-fulfilling nature of dreams in amputees (Shukla, Sahu, Tripathi, & Gupta, 1982).

2. Methods

2.1. Subjects

All participants were ex-patients of six major rehabilitation centers in The Netherlands and they were approached through the physiatrists working in these centers. In total 250 ex-patients received a letter in which they were asked to participate in this study. The study has been approved by the local medical ethics committee and after the participants gave their informed consent they received a simple questionnaire.

2.2. Procedure

All persons received a simple questionnaire containing only three questions: (1) do you dream yes/no, (2) if yes, do you dream about yourself as prior to the amputation or as after the amputation, and (3) if you dream about yourself as after the amputation, when did this shift in dream content took place: (a) immediately, (b) between 1 and 6 months, (c) between 6 and 12 months, (e) after 12 months. Additionally participants were asked to fill out their gender, current age and the age at which the first amputation was performed. Further they were asked to fill out the reason for amputation, type of amputation (upper or lower limb), single or bilateral amputation, level of amputation (proximal or distal) and side of amputation (dominant or non dominant side). The subjects did not receive any payment for their participation.

Statistical analysis was performed by using SPSS for Windows. For interval data independent sample *t*-tests were performed. Differences in variation between the samples of comparison were checked with Levene's test for equality of variances and if necessary the appropriate adjustments were made in the degrees of freedom. Dichotomous data were analyzed using χ^2 analysis.

3. Results

In total 190 persons participated in the study (123 male, 67 female, mean age 55.3 yrs, *SD* 17.7; age range 25–80 yrs). The mean time that elapsed after the amputation was 12.0 yrs (*SD* 14.2). The amputation characteristics are summarized in Table 1. Due to missing dream-data the results of 3 participants have been discarded from the analysis. Of the remaining participants 146 (78%) reported that they were dreaming and 41 subjects denied having any dreams (22%). Of the "dreamers" 4% ($n = 8$) could not recall the topics of their dreams and 30 subjects (21 %) of the "dreamers" dreamt on a regular basis about themselves as after the amputation. However, 45 participants (31%) were dreaming solely about the situation prior to amputation and 54 participants (37%) were dreaming in a mixed way (about the situation prior to as well as after the amputation). No clear relation was found between dreaming and amputation characteristics or time elapsed after the amputation (see Table 2).

There was, however, a significant effect of age. Participants who dreamt about their body as before the amputation where significantly older (59.3 yrs) than the participants who dreamt about their body as after the amputation (51 yrs) ($p = .0041$). Furthermore, the participants who dreamt about their body as before the surgery were amputated at a significantly older age (49.2 yrs) than the participants who dreamt about their

Table 1
Amputation characteristics

	% (*n*)
Reason amputation	
Congenital	5 (9)
Trauma	34 (64)
Vascular	38 (73)
Oncology	14 (26)
Other reasons	9 (18)
Amputation type	
Upper limb	12 (22)
Lower limb	90 (172)
Upper and lower limb	2 (3)
Bilateral amputation	
Bilateral amputation[a]	13 (25)
Bilateral upper limb	1 (2)
Bilateral lower limb	12 (24)
Amputation side[b]	
Amputation dominant side	55 (80)
Amputation non dominant side	45 (66)
Amputation level	
Proximal amputation[c]	66 (124)
Distal amputation	34 (64)

[a] One patient claimed to have lost all extremities.
[b] Fourty-five missing data.
[c] Through elbow (knee) or more proximal.

Table 2

	Dreaming about the body as before the amputation ($n = 45$)	Dreaming about the body as after the amputation ($n = 30$)	
Years after amputation: *Mean* (*SD*)	10.1 (13.2)	13.1 (12.6)	ns[a]
Current age: *Mean* (*SD*)	59.3 (17.0)	51.0 (16.4)	0.041[a]
Age at which the amputation was performed	49.2 (21.6)	37.9 (20.9)	0.029[a]
Vascular reason for amputation			0.002[b]
Yes (26)	22 (85)	4 (15)	
No (49)	23 (47)	26 (53)	
Traumatic reason for amputation			ns[b]
Yes (28)	14 (50%)	14 (50%)	
No (47)	31 (66%)	16 (34%)	
Proximal amputation			ns[b]
Yes (47)	30 (64%)	17 (36%)	
No (27)	15 (56%)	12 (44%)	
Amputation of dominant side			ns[b]
Yes (33)	22 (67%)	11 (33%)	
No (25)	13 (52%)	12 (48%)	
Amputation			ns[b]
Upper extremity (6)	2 (33%)	4 (67%)	
Lower extremity (69)	43 (62%)	26 (38%)	
Gender			ns[b]
Female (25)	14 (56%)	11 (44%)	
Male (50)	31 (62%)	19 (38%)	

Amputees who dream variable (with or without the amputated extremity) are excluded from this analyses.
[a] Results of independent sample *t*-test.
[b] Results of χ^2 analysis.

body as after the amputation (37.9 yrs) ($p = .029$). These age-related findings are in accordance with the result that participants with a vascular reason for amputation dreamt more frequently about their body as before the amputation (85%) than participants with other reasons for amputation (47%) ($p = .002$). Indeed, amputations on basis of vascular pathology are performed more often at an older age. None of the other amputation characteristics, however, was related to the content of dreams.

The participants who reported that they were dreaming about themselves as after the amputation, indicated that the shift of the dream content took place more or less immediately (46%), or within the 6 months period after the amputation (31%). Nine percent indicated that the shift took place between 6 and 12 months and 14% reported a shift 1 year or more after the amputation.

4. Discussion

In spite of the fact that the primary and secondary motor cortices have been "re-mapped" after amputation, leading to the plausible expectation that this would lead to a permanent alteration of the body scheme, other brain systems, especially those involved in dreaming, seem to re-create the absent limb over and over again, even years after amputation. In only 30 participants the system adapted fully to the actual body status, in the remaining 108 participants there was still a revival of the absent limb during dream activities, even when the amputation took place more than 12 years ago.

So, it seems that although the sensory and motor maps in the brain proved to be highly dynamic and adaptive as a result of experience there remains a "deeper layer" that is not so sensitive to change, but generates a rather stable representation of the body as it was. How can we explain this "representational stability"? Could it be that there exists an abstract, genetically hardwired blueprint of the body that remains relatively stable in spite of the dramatic alteration that took place in the "real" body? This idea of a hardwired blueprint is not new. Melzack, Israël, Lacroix, and Schultz (1997) discussed phantom limb sensations in subjects born without limbs. They argued that the basic experience of the body is not solely based on information pathways fed by sensory input, but that the body image is determined also partly by genetic factors. Furthermore, Melzack (2001) stressed that the body is felt as a unity, partly independent of sensory input. The anatomical substrate of this body-self feeling was termed the neuromatrix. The neurons in this matrix are genetically programmed to produce some sort of "wholeness" of the body.

The present (dream) data are in accordance with these findings, in that they indicate that there are limits to the experience-dependent changes in brain networks. It seems that changes in the sensory input do not influence the body image at all levels of the network.

4.1. Age dependency

The representational stability seems to increase with age, as is reflected by the significant age-effect: The older one is when amputated, the more unlikely it is that the body image changes. This age-effect is intriguing and deserves some further attention. Two explanations may be given for this age effect. First, it may be that a relationship exists between the duration of the original body image (blueprint) and the stability of this image after damage to the "lay-out" of the body. The longer the intact body and by this the original image exists, the more likely it is that it will not change. However, it may also indicate that the adaptive capacity of the brain declines when one becomes older. In that case the system is not able to change the image. Research about the latter argument is more or less lacking. However, the fact that many younger amputees show also a stability of the (original) body image after amputation indicates that a relationship with the duration of the image can not provide the final answer.

4.2. Observation of movements made by others

Furthermore, persons with an amputated limb see, more or less continuously, the limb-movements of others which may influence their own limb-representation. This is not at all a trivial remark, since it is known that the observation of movements activates more or less the same brain areas as actually performing these movements. Action observation activates areas in the premotor cortex as well as in the posterior parietal cortex (see Buccino et al., 2001; Rizzolatti, 2005). The fact that the posterior parietal lobe is activated during action observation is interesting for the present discussion, since it is argued that this brain area plays a role in the formation of movement images.

4.3. Concluding remarks

Although caution remains necessary, the study seems to show that, although the brain can be characterized as a biological system, permanently adapting to changes in the sensory input, it shows also a remarkable stability in other domains. We admit that the present study has its limitations. The data-collection method is rather simple, more sophisticated methods could have been used. Despite these limitations the results, however, may shed some light on one of the most mysterious neural phenomena, the body image.

Declaration of interests

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